Section 3
Results of Infiltration Tests in Disturbed Urban Soils (Task 1)

The data collected during these tests, and the detailed statistical analyses, are included in Appendices B through F. Appendix B lists the observed infiltration rates for all tests, Appendix C contains summaries of site conditions and the fitted infiltration equation parameters, and Appendices D through F show the factorial test calculations and models.

Calculated Infiltration Rates and Fitted Models

Exploratory Data Analyses

The initial analysis was to prepare simple plots of the infiltration data in order to observe major trends and groupings of the data. Three-D plots were prepared for the compaction and moisture factors for each major soil texture (sand and clay). These plots are shown in Figures 3-1 and 3-2. Four general categories were observed to be unique:

- Noncompacted-sandy soils
- Compacted-sandy soils
- Dry-noncompacted-clayey soils
- All other clayey soils (compacted and dry, plus all saturated conditions)

These analyses show that compaction had the greatest effect on infiltration rates in sandy soils, with little detrimental effects associated with soil moisture. Compaction and moisture affected clayey soils. Compaction had about the same effect as moisture on clayey soils, with saturated-compacted-clayey soils having the least effective infiltration.

Fitting Observed Data to the Horton Infiltration Equation

Data from each site test was fitted to the Horton infiltration equation and the equation coefficients were statistically analyzed using factorial analysis procedures. Figures 3-3 through 3-6 show the observed infiltration rates, and the fitted Horton equation parameters for the four general categories, as found in the three dimensional plots of Figure 3-1 and 3-2.

Figure 3-3 demonstrates that noncompacted sand is the urban soil condition with the greatest infiltration potential. In addition, this condition is the only one of the four major categories that had an obvious decrease in infiltration with time during the tests. The observed infiltration rates occur in a relatively even, but broad, band. Three of the 36 tests had very low initial rates, but were within the typical band of observations after about ten minutes. Some initial wetting, or destruction of a surface crust, was apparently necessary before the site infiltration rate stabilized. Table 3-1 summarizes the observed Horton equation parameter values, compared to the typical published parameter values, for sandy soils.

The observed infiltration ratess differed greatly from the published values. Typically, published values reflected moisture effects to the Horton infiltration equation and the equation coefficients, while the observations indicated very small effects associated with moisture for sandy soils, and very large effects associated with compaction. The constant-final-infiltration rates were larger than typically assumed, with infiltration rates for noncompacted, sandy soils of about 350 mm/hr (14 in/hr), ranging from about 125 to 635 mm/hr (5 to 25 in/hr) during the tests. The comparable published rates were less than 25 mm/hr (1 in/hr). The infiltration rates leveled-off to the constant-final values after about 30 to 45 min.

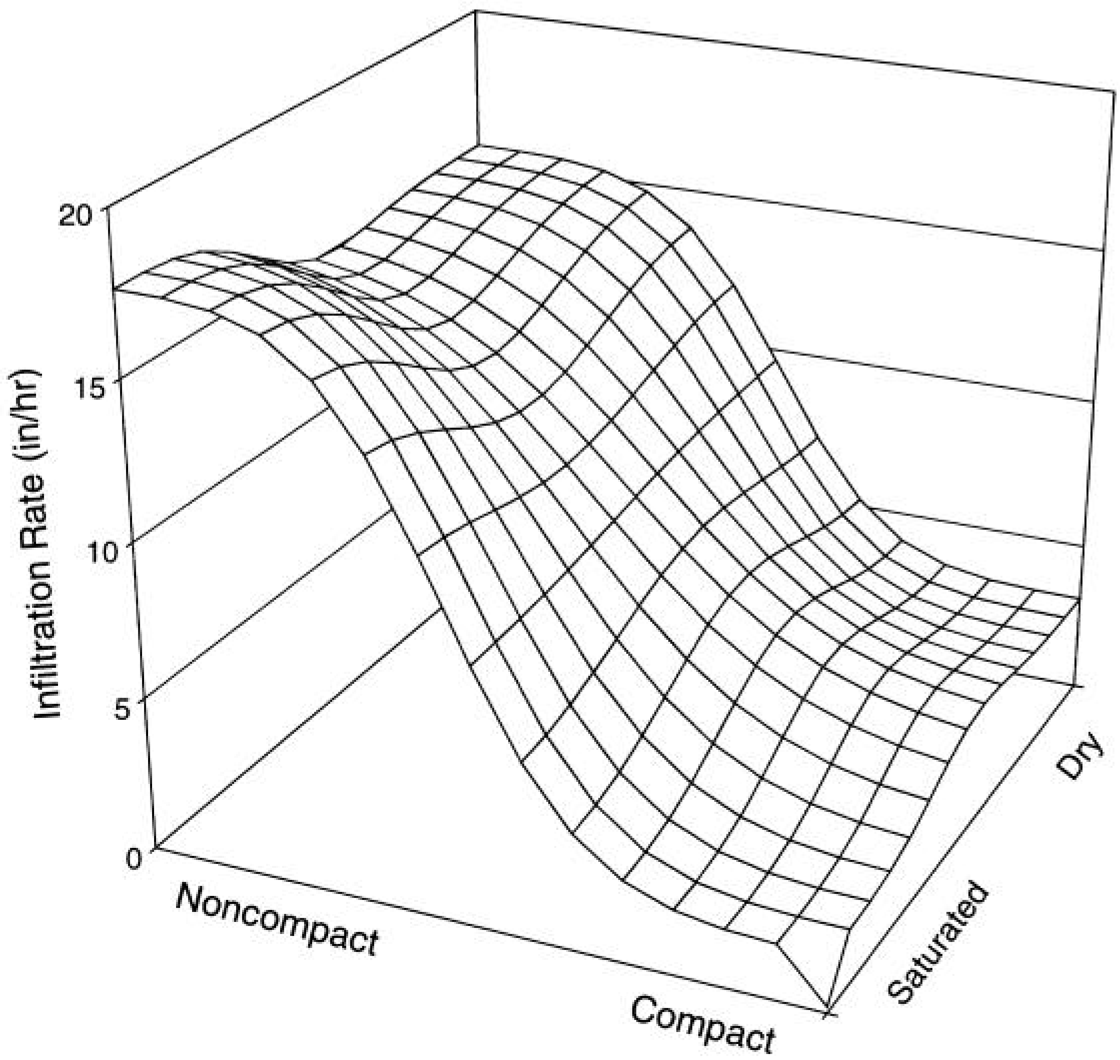


Figure 3-1. Three dimensional plot of infiltration rates for sandy soils.

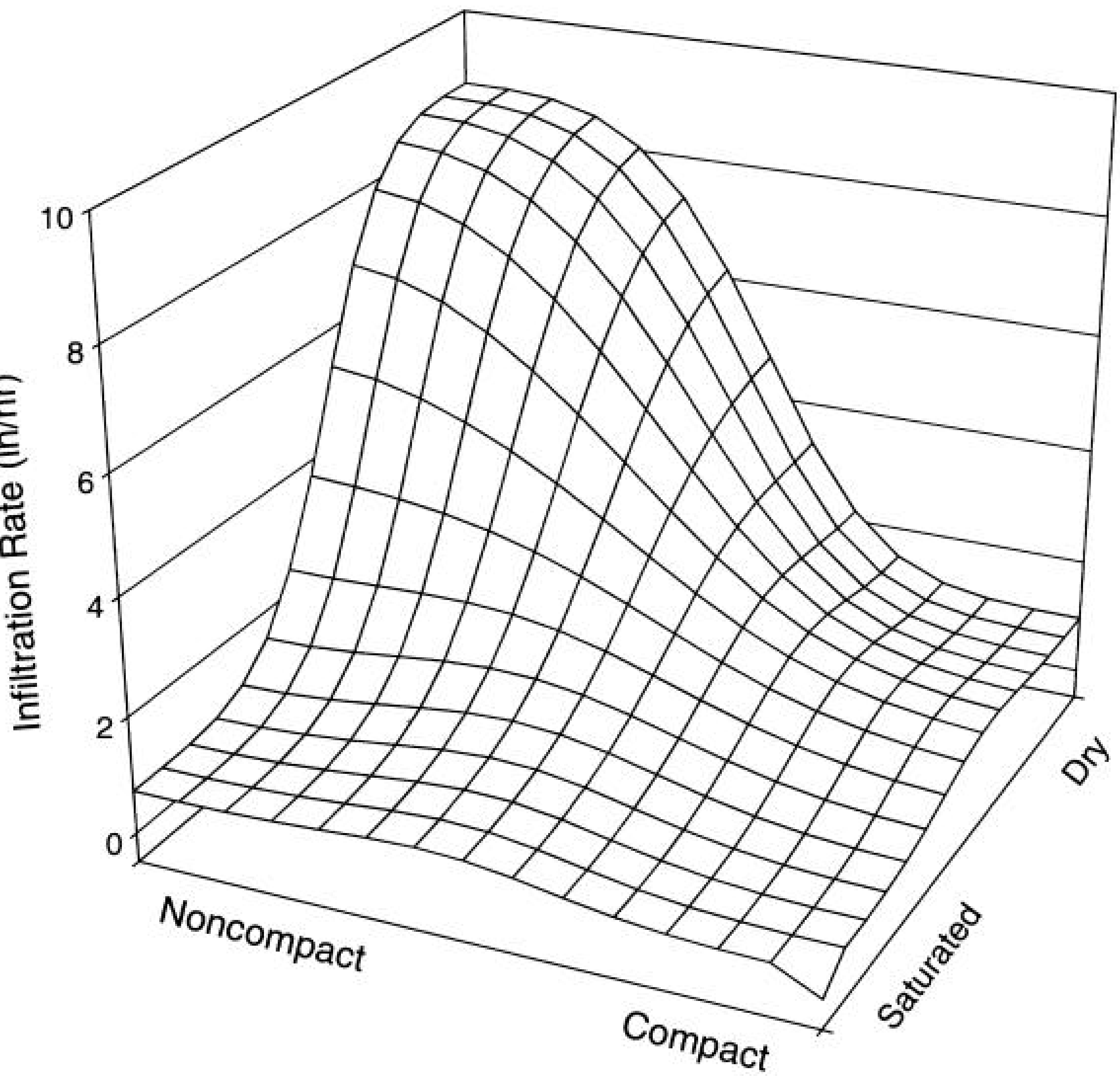


Figure 3-2. Three dimensional plot of infiltration rates for clayey soils.

Table 3-1. Observed and published Horton equation parameter values for sandy soils

	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	range	mean	range	mean	Range
Observed noncompacted-sandy soils	990 (39)	110–3710 (4.2–146)	380 (15)	10–640 (0.4–25)	9.6	1.0–33
Observed compacted-sandy soils	380 (15)	3–2200 (0.1–86)	46 (1.8)	3–240 (0.1–9.5)	11	1.8–37
Published values		43–250 (1.7–10)		7.6–11 (0.30–0.45)		0.069

Figure 3-4 shows the observed infiltration rates and the fitted Horton equation parameter values for compacted-sandy soils. The observed rates are significantly less than for the above noncompacted-sandy soils. The effect of compaction on sandy soils is very large, reducing the infiltration rates by between 5 and 10 times. Some initial rates were very large, but the rates decreased quickly with time. After 20 to 30 minutes, they are all within about 0 to 500 mm/hr (0 to 20 in/hr), with most of the 39 observations less than 125 mm/hr (5 in/hr).

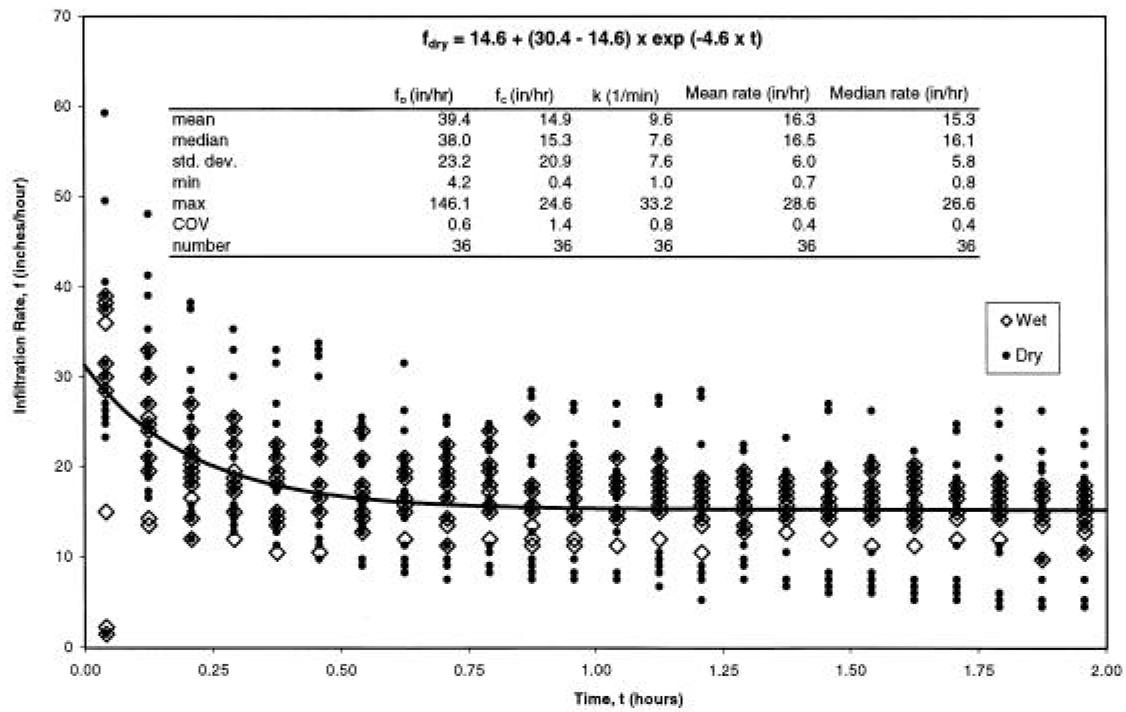


Figure 3-3. Infiltration measurements for noncompacted-sandy soils.

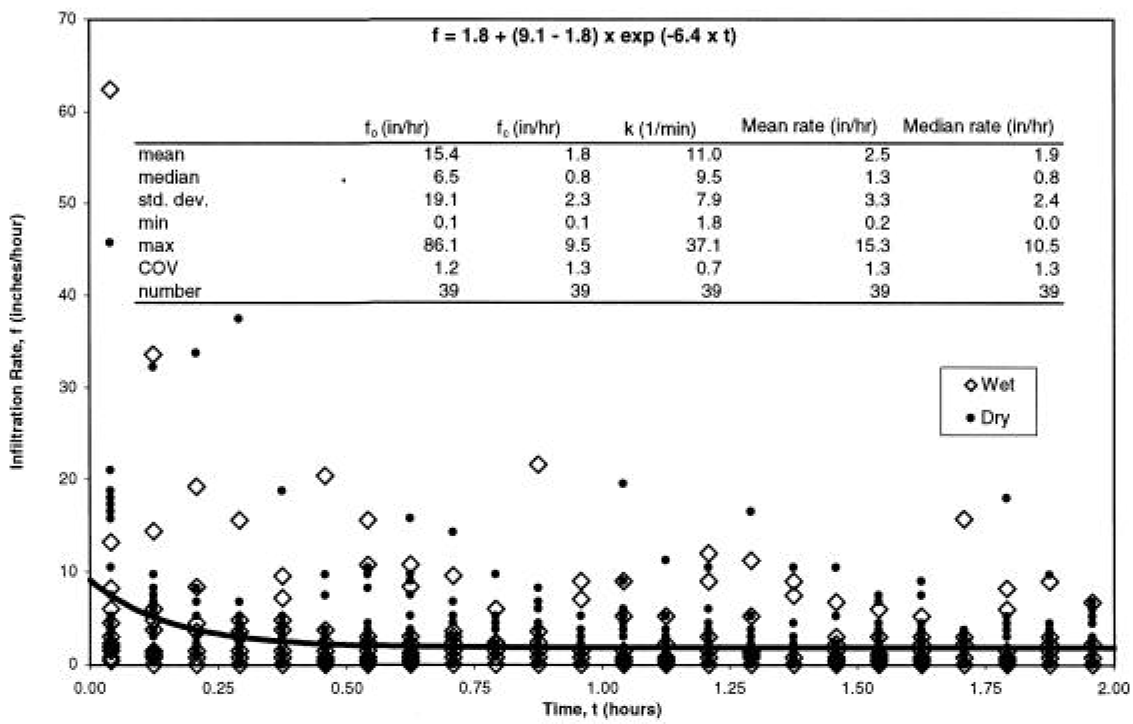


Figure 3-4. Infiltration measurements for compacted-sandy soils.

Figure 3-5 is a similar plot for dry-noncompacted-clayey soils which was the highest infiltration rate category for clayey soils. No significant change in infiltration rates were seen as a function of time, with all test average values within the range of 8 to 500 mm/hr (0.3 to 20 in/hr) and a mean rate of about 230 mm/hr (9 in/hr) for all 18 tests. Figure 3-6 shows the observed test results for the other clayey soils (dry and compact, and all saturated conditions). These rates were the lowest observed. Some initial values of the saturated-noncompacted-clayey soils were greater than later values, although most of the 60 sets of test data indicated infiltration rates were within a relatively narrow range of less than 125 mm/hr (5 in/hr). Table 3-2 shows the observed Horton equation parameters as compared to published values. The mean clayey-soil rates of infiltration were all greater than the published values, although the compacted and saturated clays were much closer to the published values than the observed rates of dry clayey soil.

Table 3-2. Clayey soil Horton Equation parameter observed and published values

	f_o mm/hr (in/hr)		f_c mm/hr (in/hr)		k (1/min)	
	mean	range	mean	range	mean	range
Observed dry-noncompacted-clayey soils	460 (18)	64–1500 (2.5–58)	170 (6.6)	3–610 (0.1–24)	8.8	-6.2–19
Published values for dry-clayey soils		30–50 1–2		0–1 0–0.05	0.069	
Observed for all other clayey soils (compacted and dry, plus all saturated conditions)	86 (3.4)	0–1200 (0–48)	10 (0.4)	-15–170 (-0.6–6.7)	5.6	0–46
Published values for saturated-clayey soils		8–18 (0.3–0.7)		0–1 (0–0.05)	0.069	

Time-Averaged Infiltration Rates

Because of the wide range in observed rates for each of the major categories, it may not matter much which infiltration rate equation is used. The residuals are all relatively large and it may be more important to consider the random nature of infiltration about any fitted model and to address the considerable effect that soil compaction has on infiltration. It may therefore be necessary to use a Monte Carlo stochastic component in a runoff model to describe this variation.

Table 3-3 shows the measured infiltration rates for each of the four major soil categories, separated into several time increments. This table shows the observed rates of infiltration for each test averaged for different storm durations (15, 30, 60, and 120 min). Also shown are the ranges and COV values for each duration and condition. As an example of a Monte Carlo type approach, a routine in a model could select an infiltration rate, associated with the appropriate soil category, based on the storm duration. The selection of a storm-averaged rate would be from a random distribution (likely a log-normal distribution) using the mean and standard deviation values shown on this table.

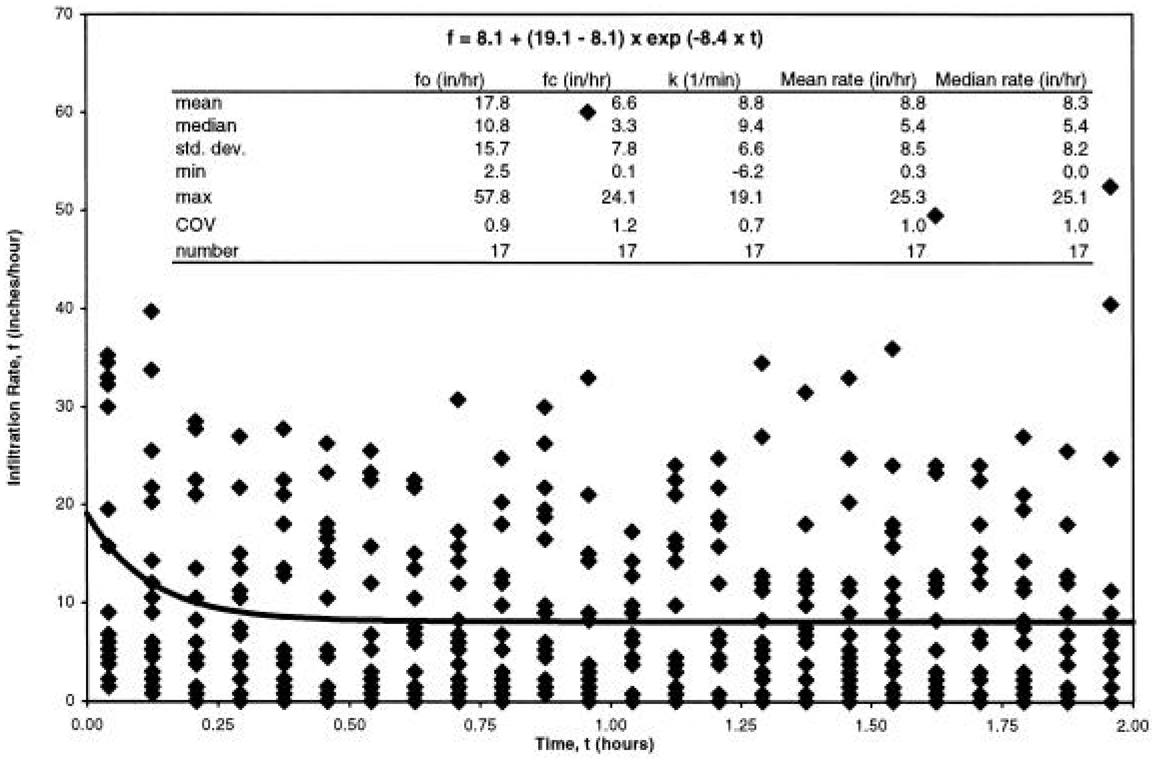


Figure 3-5. Infiltration measurements for dry-noncompacted-clayey soils.

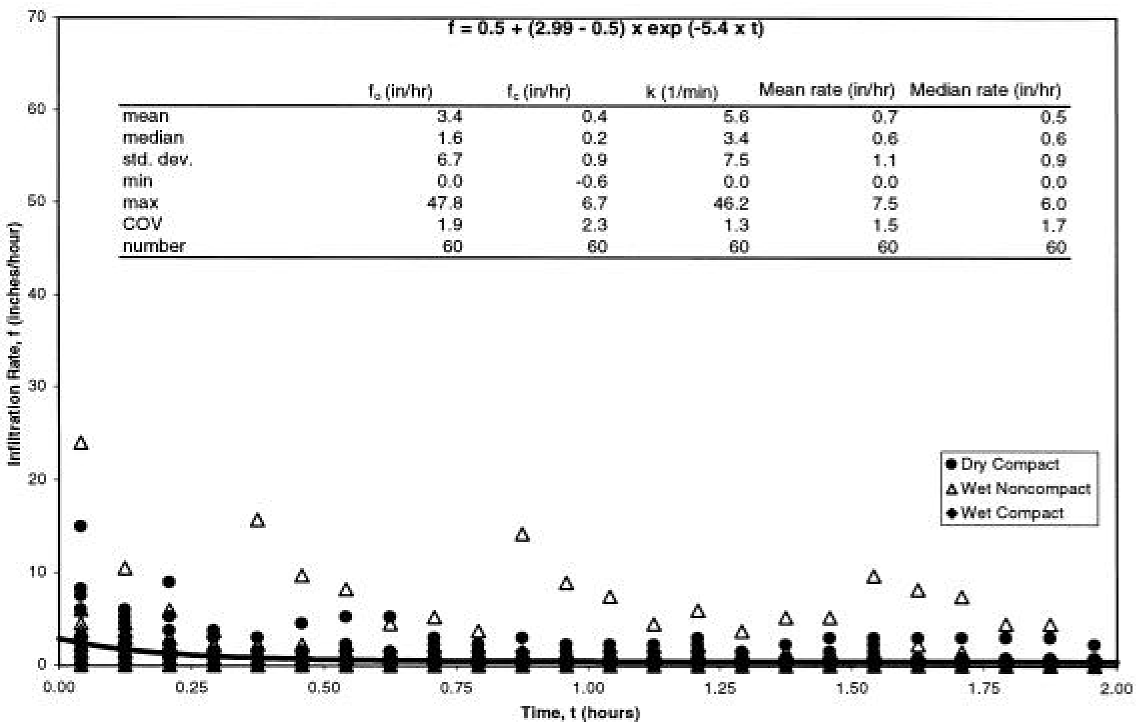


Figure 3-6. Infiltration measurements for wet-noncompacted, dry-compacted, and wet-compacted clayey soils.

Table 3-3. Soil infiltration rates for different categories and storm durations

Sand, Noncompacted (in/hr)

	15 minutes	30 minutes	60minutes	120 minutes
mean	22.9	19.5	16.9	15.0
median	25.0	19.7	17.4	15.7
std. dev.	10.6	9.1	8.0	7.2
min	1.3	0.8	0.6	0.5
max	43.0	38.0	32.4	28.6
COV	0.5	0.5	0.5	0.5
number	36	36	36	36

Sand, Compacted

	15 minutes	30 minutes	60minutes	120 minutes
mean	6.7	4.9	3.8	3.0
median	4.3	2.9	1.9	1.3
std. dev.	8.8	6.9	5.4	4.4
min	0.1	0.2	0.2	0.2
max	36.5	29.1	23.8	21.3
COV	1.3	1.4	1.4	1.5
number	39	39	39	39

Clay, Dry, Noncompacted

	15 minutes	30 minutes	60minutes	120 minutes
mean	12.7	10.8	9.6	8.8
median	7.6	6.3	5.8	5.4
std. dev.	10.8	9.5	8.9	8.5
min	1.0	0.5	.5	0.3
max	32.0	29.0	26.5	25.3
COV	0.9	0.9	0.9	1.0
number	18	18	18	18

All other clayey soils (compacted and dry, plus all saturated conditions)

	15 minutes	30 minutes	60minutes	120 minutes
mean	1.8	1.3	1.0	0.7
median	1.3	1.0	0.8	0.6
std. dev.	2.3	1.7	1.3	1.1
min	0.0	0.0	0.0	0.0
max	13.5	11.4	9.4	7.5
COV	1.3	1.3	1.4	1.5
number	60	60	60	60

Figures 3-7 through 3-10 are probability plots showing the observed infiltration rates for each of the four major soil categories, separated by the four event durations. Each figure has four separate plots representing the storm event averaged infiltration rates corresponding to storm durations from 15 min to 2 hr. As indicated previously, the infiltration rates became relatively steady after about 30 to 45 minutes during most tests. Therefore, the 2-hr average rate could likely be used for most events of longer duration. As expected, these plots which show higher rates for shorter rain durations. The probability distributions are closer to being log-normal than the normal plots shown. However, because three of the test categories had many observations of zero-infiltration rates, log-normal probability plots were not possible.

For this approach, the soil texture and compaction classification would remain fixed for an extended simulation period (unless the soils underwent an unlikely recovery operation to reduce soil compaction). Clayey soils would be affected by the antecedent, inter-event period which would define the moisture level at the beginning of the rains. Soil moisture recovery periods are highly dependent on site-specific soil and climatic conditions and are calculated using various methods in continuous simulation urban runoff models. The existing models assume that the recovery period is much longer than the period needed to produce saturation. As noted above, saturation (defined here as when the infiltration rate reaches a constant value) occurred in less than an hour during these tests. A simple estimate of the time needed for recovery of soil moisture levels is given by the NRCS in TR-55 (McCuen 1998). The NRCS developed three antecedent soil moisture conditions as follows:

- Condition I: soils are dry but not to the wilting point
- Condition II: average conditions
- Condition III: heavy rainfall, or lighter rainfall and low temperatures, have occurred within the last five days, producing saturated soil.

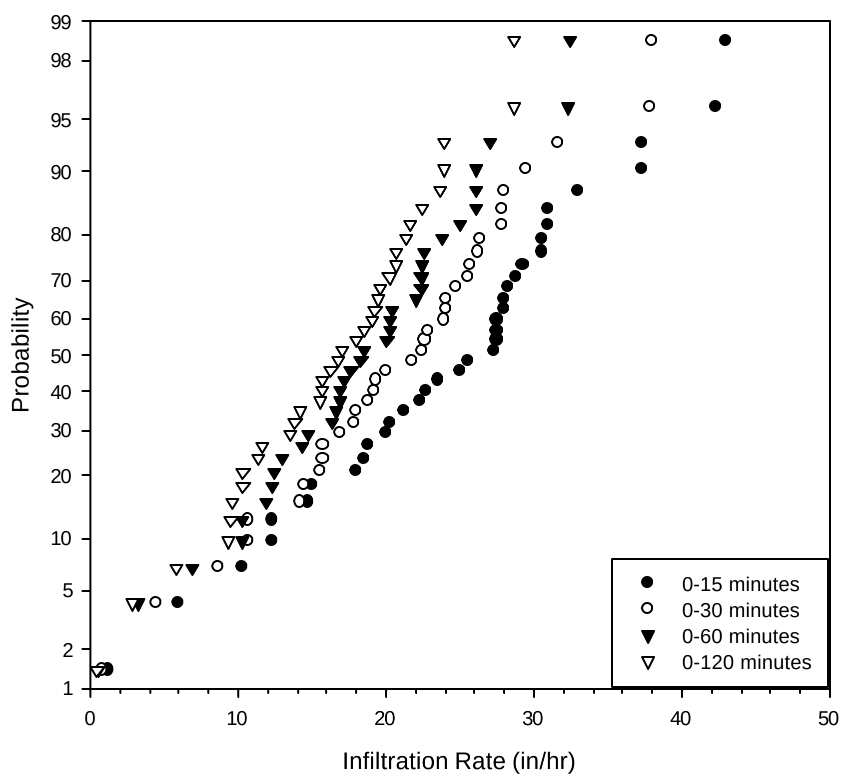


Figure 3-7. Probability plots for infiltration measurements for noncompacted-sandy soils.

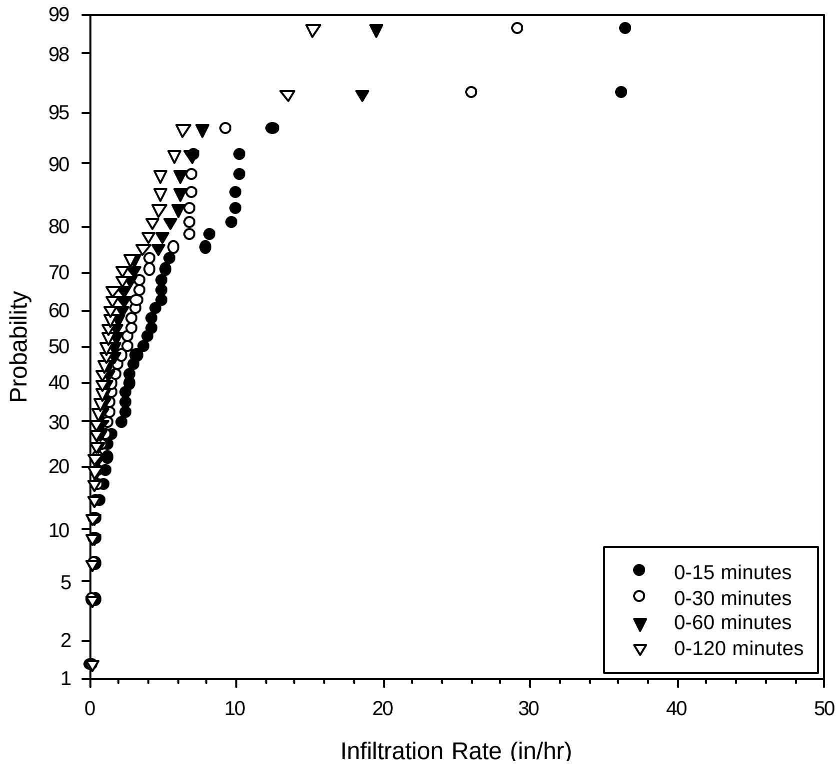


Figure 3-8. Probability plots for infiltration measurements for compacted-sandy soils.

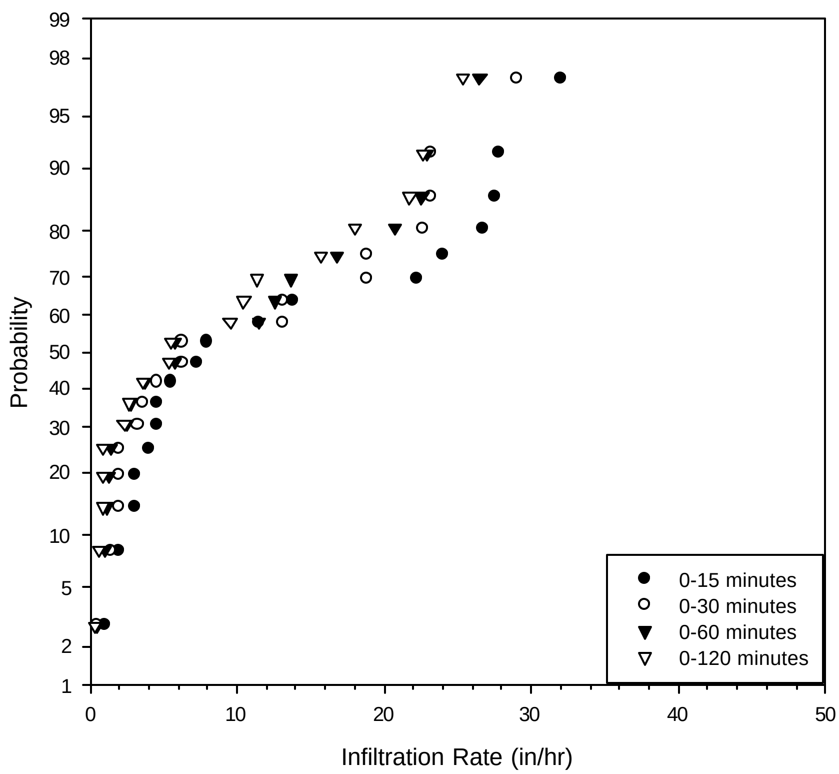


Figure 3-9. Probability plots for infiltration measurements for dry-noncompacted-clayey soils.

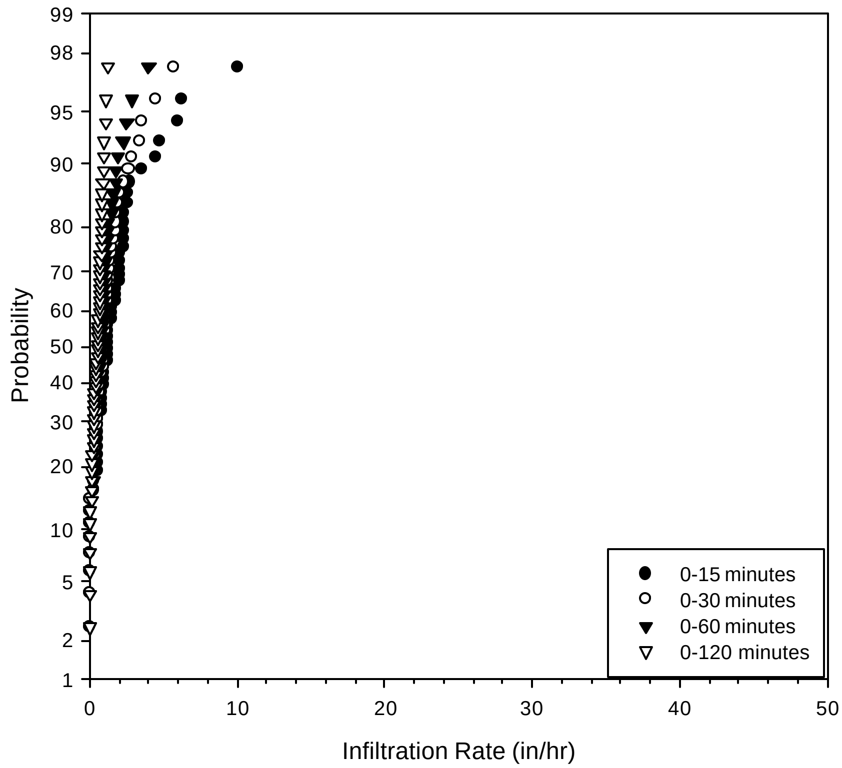


Figure 3-10. Probability plots for infiltration measurements for wet-noncompacted, dry-compacted, and wet-compacted, clayey soils.

Seasonal rainfall limits (McCuen 1998) for these three conditions are presented in Table 3-4 (from the NRCS). Therefore, as a rough guide, saturated-soil conditions for clayey soils may be assumed if the preceding 5-day total rainfall was greater than about 25 mm (1 in.) during the winter, or greater than about 50 mm (2 in.) during the summer. Otherwise, the "other" infiltration conditions for clayey should be assumed.

Table 3-4. Total five-day antecedent rainfall for different moisture conditions

	Dormant Season mm/hr (in/hr)	Growing Season mm/hr (in/hr)
Condition I	<13 (0.5)	<36 (1.4)
Condition II	13–28 (0.5–1.1)	36–53 (1.4–2.1)
Condition III	>28 (1.1)	>53 (2.1)

Box Plot Analyses of Infiltration Measurements

Tukey box plots (Figures 3-11 through 3-17) were prepared to obtain a graphical comparison of the four major soil categories for the seven infiltration parameters examined: the Horton f_o, f_c, and k parameters, plus the time-averaged infiltration rates for durations of 15, 30, 60 and 120 min. Each box represents the data for one of the major soil categories. The length of the boxes indicate the 25th and 75th percentiles of the data, the line inside the box marks the value of the 50th percentile (median), the capped bars indicate the

10th and 90th percentiles, and the circular symbols show the extreme data values. The percentiles for all analysis are summarized in Table 3-5.

Figure 3-11 shows that Horton's initial infiltration rate (f_o) values are similar for the soil groups clay-other and sand-compact. The soil groups clay-dry-noncompact and sand-noncompact are also similar. This pattern is even more evident in Figure 3-12, which shows Horton's infiltration capacity (f_c) (constant, final rate). As shown in Figure 3-13, the Horton decay constant (k) does not have a large variation from one soil group to the next. The percentiles for the average infiltration rates for the different storm durations (15, 30, 60 and 120 minutes) showed much more variation between soil groups than the other parameters (Figures 3-14 through 3-17). The sand, non-compact, category has the fastest rates, along with the widest range of values, while the clay, other, category, has the slowest rates, and the least variation (all close to zero). The other data groupings also show relatively wide variations in the time-averaged infiltration rates, further re-enforcing the need to consider uncertainty during infiltration analyses.

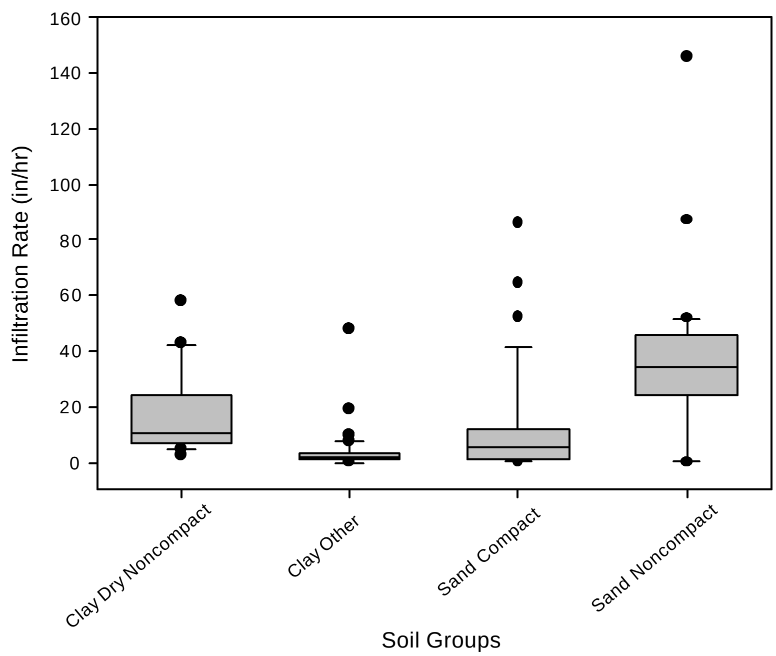


Figure 3-11. Horton's Equation values for initial infiltration - f_o.

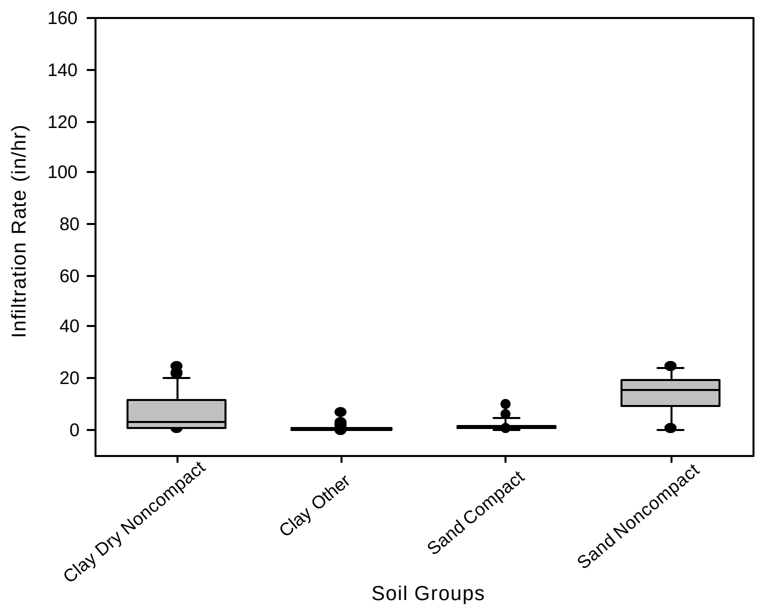


Figure 3-12. Horton's Equation for infiltration capacity – f_c.

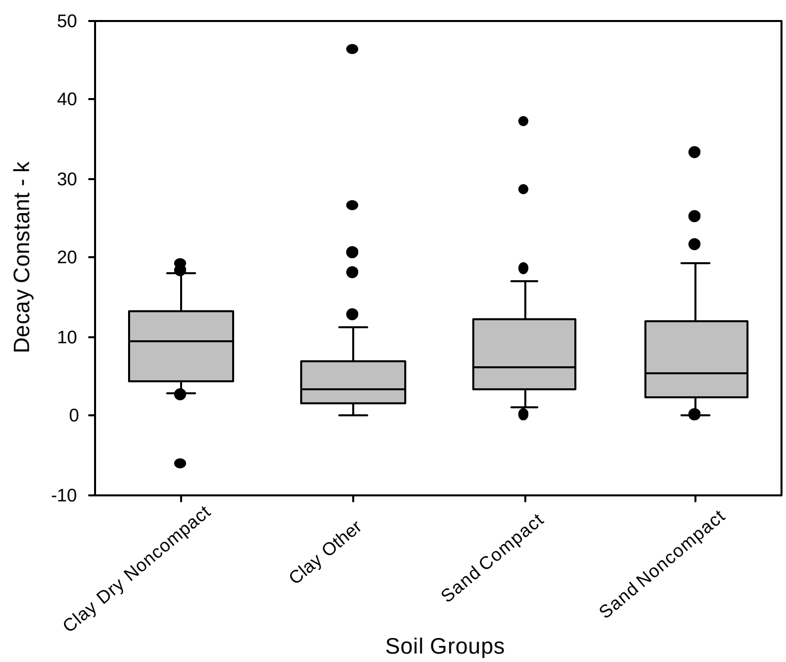


Figure 3-13. Horton's Equation decay constant – k.

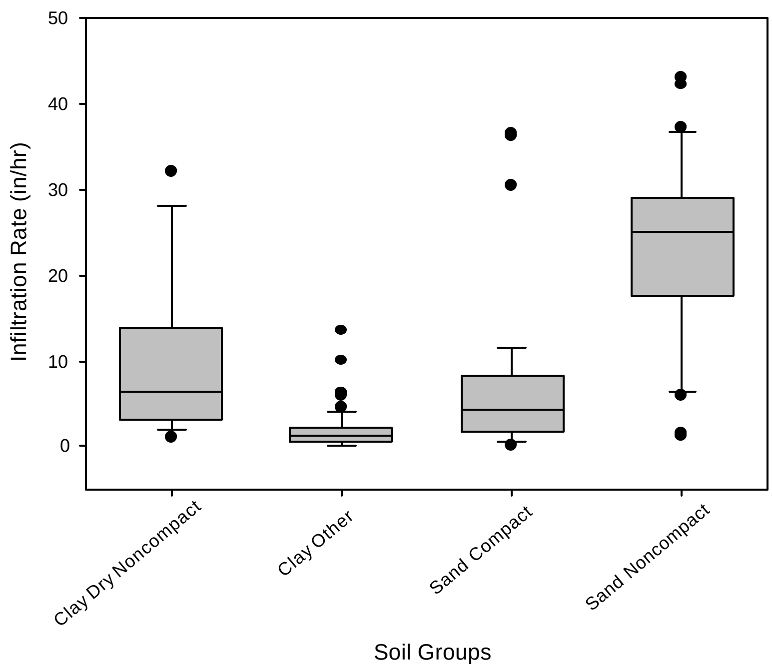


Figure 3-14. Infiltration rates at 15 minutes.

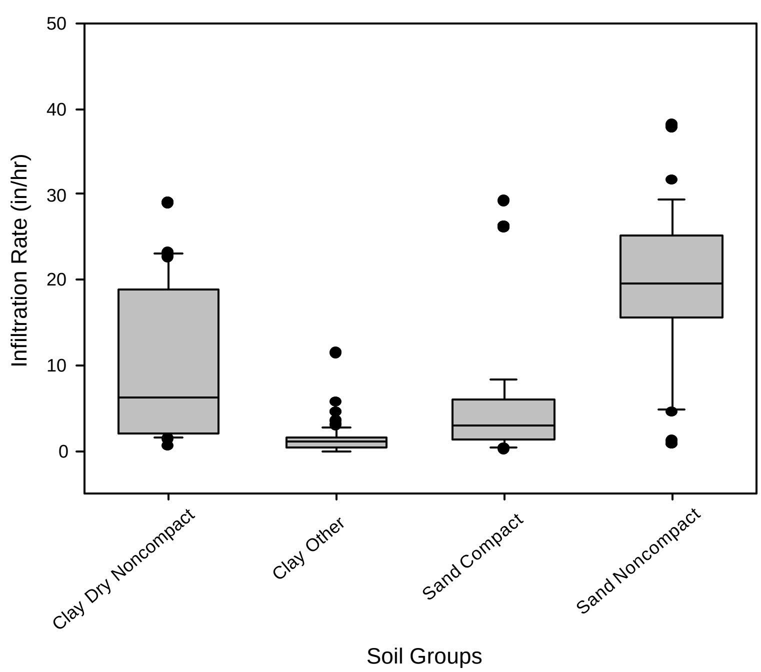


Figure 3-15. Infiltration rates at 30 minutes.

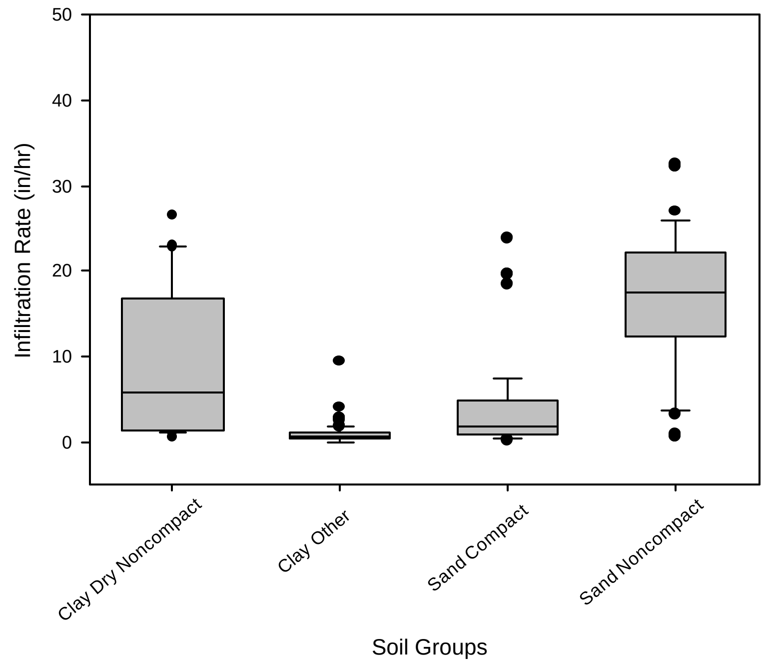


Figure 3-16. Infiltration rates at 60 minutes.

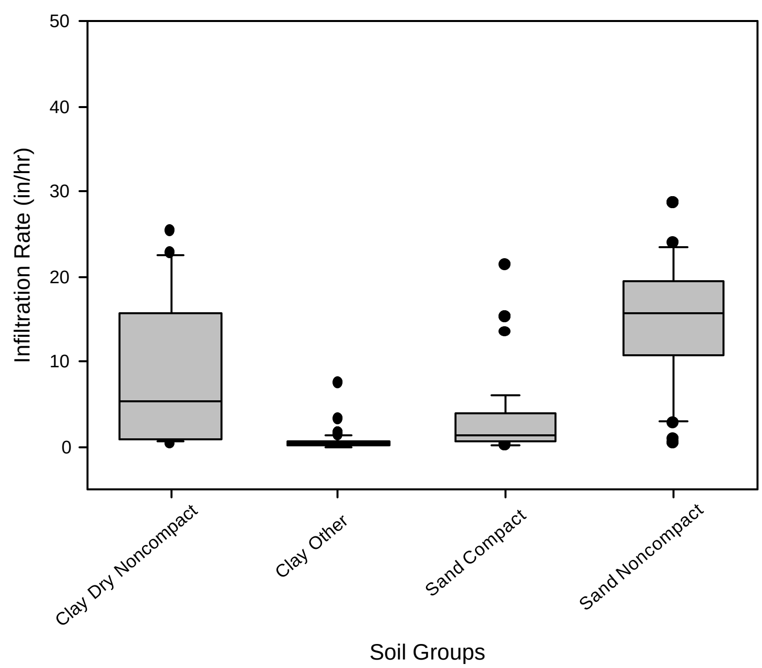


Figure 3-17. Infiltration rates at 120 minutes.

Table 3-5. Summary of box plot probabilities for the infiltration parameters.

Infilatration Parameter	Soil Group	90%	75%	Median	25%	10%
f_o (in/hr)	Clay - Dry Noncompact	42	24	11	7	5
	Clay - Other	7	3.75	2	1	0
	Sand - Compact	42	12	5	1.5	0
	Sand - Noncompact	52	46	34	24	0.25
f_c (in/hr)	Clay - Dry Noncompact	20	12	3	0.75	0.25
	Clay - Other	0.75	0.5	0.25	0	0
	Sand - Compact	5	1.25	0.5	0.25	0
	Sand - Noncompact	24	19	15	9	0
k	Clay - Dry Noncompact	18	13	9.5	4.5	3
	Clay - Other	11	6.5	3.75	1.75	0
	Sand - Compact	17	12	6	3	1
	Sand - Noncompact	19	12	5	2	0
15 minutes averaged (in/hr)	Clay - Dry Noncompact	28	14	6	3	2
	Clay - Other	4	2	1	0.25	0
	Sand - Compact	12	8	4	2	0.5
	Sand - Noncompact	37	29	25	17.5	6.5
30 minutes averaged (in/hr)	Clay - Dry Noncompact	23	19	6	2	1.75
	Clay - Other	2.5	1.75	1	0.25	0
	Sand - Compact	8	6	2.75	1.75	0.25
	Sand - Noncompact	29	26	20	16	5
60 minutes averaged (in/hr)	Clay - Dry Noncompact	23	17	6	2	1.5
	Clay - Other	2	1	0.5	0.25	0
	Sand - Compact	0.75	5	2	1	0.25
	Sand - Noncompact	26	22	17.5	12	4
120 minutes averaged (in/hr)	Clay - Dry Noncompact	22.5	16	5	1	0.75
	Clay - Other	1.25	0.75	0.5	0.25	0
	Sand - Compact	6	4	1	0.5	0
	Sand - Noncompact	24	20	16	11	3

Relationships Between Infiltration Parameters and Site Conditions

A series of statistical tests were conducted to investigate the inter-relationships and/or redundancies of the infiltration parameters and site conditions. These tests were all conducted using SYSTAT, version 8. The first analysis was a standard Pearson correlation matrix which identifies simple correlations between parameters. The results of this test identified a few pairs of infiltration parameters that were highly correlated with one another, but no site conditions were highly correlated to any other site conditions or to any of the infiltration parameters. This indicates that the site factors examined were generally independent and could be used in further analyses, and there may not be much real difference when choosing between alternative infiltration models because of the large amount of variability in the measured rate parameters. The correlations greater than 0.7 are presented in Table 3-6. It is seen that most of the time-averaged rates are highly correlated with each other and with the Horton initial and final rate parameters (but not the Horton decay rate parameter, k).

More complex inter-relationships were investigated by conducting a hierarchical cluster analyses. Figure 3-18 is a dendogram illustrating simple and complex relationships between the tested parameters and site conditions. The time-averaged rates are all closely related (as expected) and are obviously not independent indicators of infiltration conditions. The Horton final-infiltration-rate parameter, f_c is more closely related to the time-averaged rates than to f_o, the Horton initial-rate parameter. All of the other parameters and site conditions are significantly less interrelated.

Table 3.6 Infiltration parameters and site condition correlations exceeding 0.7

Correlation with	15 minute averaged rate	30 minute averaged rate	60 minute averaged rate	120 minute averaged rate
15 minute averaged rate	---	0.994	0.979	0.958
30 minute averaged rate	0.994	---	0.993	0.994
60 minute averaged rate	0.979	0.993	---	0.979
120 minute averaged rate	0.958	0.978	0.995	---
median infiltration rate	0.825	0.854	0.878	0.825
standard deviation of infiltration rate	0.793	0.772	0.749	0.793
f_C Horton parameter	0.780	0.804	0.818	0.780
f_0 Horton parameter	0.717	0.700	NA	NA

NA- not applicable; value less than 0.7

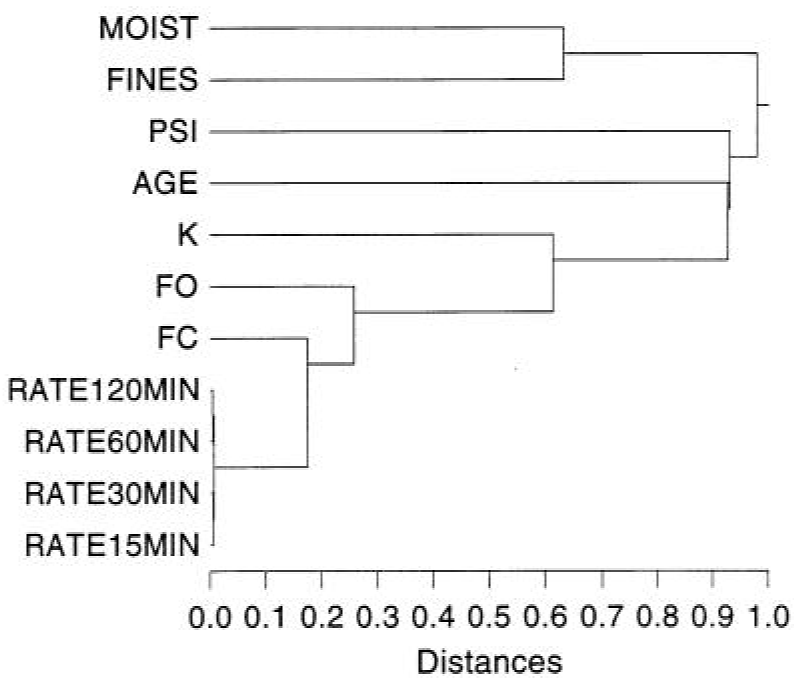


Figure 3-18. Dendogram to investigate complex inter-relationships between site conditions and infiltration parameters.

A principal component of the final analysis was to investigate groupings of the data. This analysis groups test parameters into principal component groups that are most interrelated and ranks the components in importance to explain the overall variation of the data. When testing these data, the first principal component explained about 52% of the total variance and was composed of time-averaged rate values alone (15, 30, 60, 120 minute averaged rates, plus the median rate). The second principal component explained another 12% of the total variance and was comprised of site conditions (compaction, moisture, and texture). The third component added another 8% of the variance and was dominated by the Horton rate constant k. These first three principal components contained about 72% of the total variance. The remaining 28% of the variance was associated with less important principal components that were associated with all of the site conditions and measurement parameters combined.

Factorial Analyses of Infiltration Measurements

A factorial analysis was performed on the infiltration parameters calculated from the observed field data to determine the importance of the different site characteristics. First, a 2^3 factorial design was used to evaluate all data for the effects of soil moisture, soil texture and soil compactness on each of the infiltration parameters, f_o, f_c, k, and on the time-averaged infiltration rates for 15, 30, 60 and 120 min. These analyses identified the significant site factors needed to best predict the infiltration parameters. The previous correlation tests found no redundancies in the site parameters, so all infiltration rate data and site data were used in this series of analyses.

Appendices D, E, and F contain the factorial analysis details, including the residual analyses for the different models. Figure 3-19 is an example of the basic analyses for all of the data (both sand and clay textures combined) and shows the graphical results for $f_{o.}$ It was determined, based on the pooled standard error and the probability plot of the effects, that the soil texture plus the soil compaction (T + C) has the most significant effect on f_o for this condition. The clay observations alone (Appendix F) are forced to consider the interaction of moisture and compaction, and not rely solely on the standard error or the probability plot due to the obvious non-orthogonal behavior of these parameters on the 3D plot.

The model for f_o was determined to be:

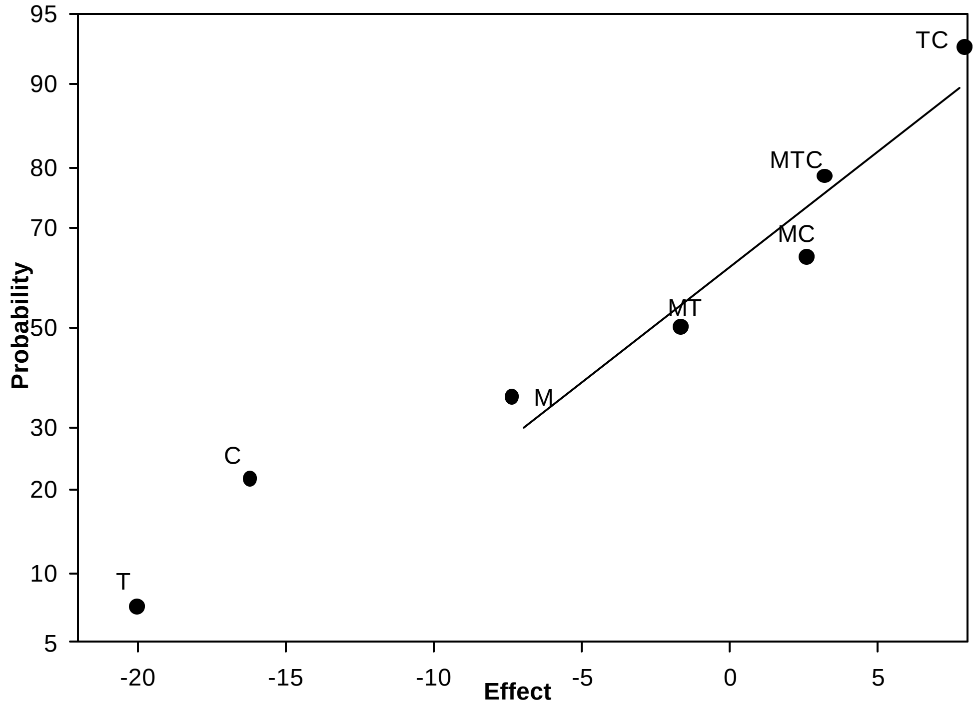
f_o = overall average ± (effect of texture/2) ± (effect of compaction/2)
or
$f_o = 17.26 \pm (T/2) \pm (C/2)$
or
$f_o = 17.26 \pm (-20.02/2) \pm (-16.19/2)$.

Therefore, four possible conditions, and predicted f_o rates, are identified:

Clay and compact (T+ and C+), $f_o = 17.26 – 10.01 – 8.08 = -0.83$in/hr, assumed to be 0 in/hr.
Clay and non-compact (T+ and C-), $f_o = 17.26 – 10.01 + 8.08 = 15.33$in/hr
Sand and compact (T- and C+), $f_o = 17.26 + 10.01 – 8.08 = 19.19$in/hr
Sand and non-compact (T- and C-), $f_o = 17.26 + 10.01 + 8.08 = 35.35$in/hr

Of course, the four significant figures for the predicted values of f_o are unreasonable, considering the large variation in the observed values.

This model was then compared with the 152 individual observed values. The resulting residuals were plotted as a probability plot (Figure 3-20). Although there are some outliers, this model is suitable for approximately 90 percent of the data (about 15 data observations do not fit the straight line very well). Table 3-7 is a summary of the results of the factorial analysis on each parameter. Some analyses showed that a combined effect (interaction) was most significant. An example of a combined effect would be the interaction of moisture and compaction (M x C).



C = Compaction, M = Moisture and T = Texture

Figure 3-19. Probability plot of the factorial analysis effects on f_o.

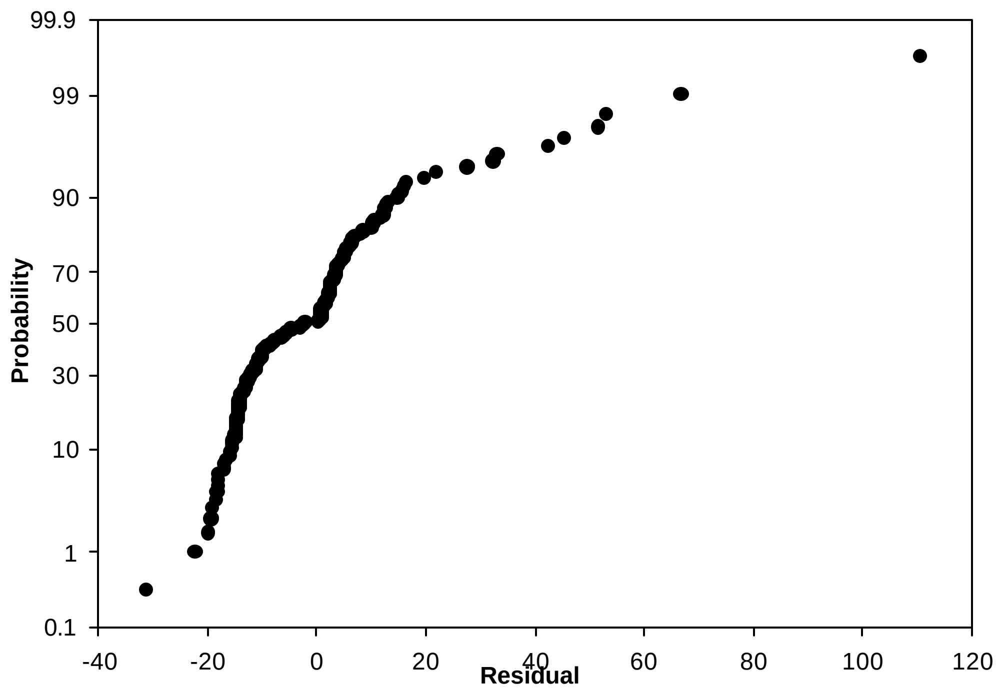


Figure 3-20. Probability plot of the residuals resulting from the comparison of the model to the observed values.

Table 3-7. All texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equations	Texture (Clay=+/Sand=-)	Compacted (Yes=+/No=-)	Model Value
f_o (in/hr)	17.26	Texture + Compaction	+	+	0 (-0.84)
		$f_o = 17.26 \pm (T/2) \pm (C/2)$	+	-	15.35
		$f_o = 17.26 \pm (-20.02/2) \pm (-16.19/2)$	-	+	19.18
			-	-	35.37
f_c (in/hr)	5.27	Texture + Compaction	+	+	0 (-1.92)
		$f_c = 5.27 \pm (T/2) \pm (C/2)$	+	-	6.43
		$f_c = 5.27 \pm (-6.02/2) \pm (-8.35/2)$	-	+	4.10
			-	-	12.45
k	8.30	Texture	+	+	5.96
		$k = 8.30 \pm (T/2)$	+	-	5.96
		$k = 8.30 \pm (-4.68/2)$	-	+	10.64
			-	-	10.64
15 minutes (in/hr)	9.80	Texture x Compaction	+	+	12.70
		$f_{15\ min} = 9.80 \pm (TC/2)$	+	-	6.89
		$f_{15\ min} = 9.80 \pm (5.81/2)$	-	+	6.89
			-	-	12.70
30 minutes (in/hr)	8.06	Texture x Compaction	+	+	10.66
		$f_{30\ min} = 8.06 \pm (TC/2)$	+	-	5.46
		$f_{30\ min} = 8.06 \pm (5.20/2)$	-	+	5.46
			-	-	10.66
60 minutes (in/hr)	6.89	Texture x Compaction	+	+	9.22
		$f_{60\ min} = 6.89 \pm (TC/2)$	+	-	4.57
		$f_{60\ min} = 6.89 \pm (4.65/2)$	-	+	4.57
			-	-	9.22
120 minutes (in/hr)	6.04	Texture x Compaction	+	+	8.20
		$f_{120\ min} = 6.04 \pm (TC/2)$	+	-	3.88
		$f_{120\ min} = 6.04 \pm (4.32/2)$	-	+	3.88
			-	-	8.20

This analysis shows that soil texture had a significant and important effect for all parameters. Therefore, to produce a model that is more sensitive and accurate, the data was separated into two groups according to texture, clay or sand, for a 2^2 factorial analysis of data. The results for the sandy texture soil are shown on Table 3-8. Compaction of the sandy soil has the greatest effect on the infiltration parameters. This analysis showed that this infiltration model is acceptable for approximately 80% of the data. See Appendix E for the complete factorial analysis of each parameter for the observed data for sandy soils.

Table 3-9 shows the results for the factorial analysis for the data corresponding to the clay texture. The effects of moisture combined with compaction have the greatest effect on the clay soils. The results show the model is good for about 80% of the data. See Appendix F for the complete factorial analysis of each parameter for the observed data for clay.

Table 3-8. Sand texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equation	Compaction	Model Value
f_o (in/hr)	24.63	Compaction $f_o = 24.63 \pm (C/2)$ $f_c = 24.63 \pm (-4.11/2)$	+ -	22.57 26.68
f_c (in/hr)	6.67	Compaction $f_c = 6.67 \pm (C/2)$ $f_c = 6.67 \pm (-13.01/2)$	+ -	0.16 13.17
k	10.42	Average k = 10.42	+ -	10.42 10.42
15 minutes (in/hr)	15.01	Compaction $f_{15\ min} = 15.01 \pm (C/2)$ $f_{15\ min} = 15.01 \pm (-16.75/2)$	+ -	6.63 23.38
30 minutes (in/hr)	12.43	Compaction $f_{30\ min} = 12.43 \pm (C/2)$ $f_{30\ min} = 12.43 \pm (-15.10/2)$	+ -	4.88 19.98
60 minutes (in/hr)	10.64	Compaction $f_{60\ min} = 10.64 \pm (C/2)$ $f_{60\ min} = 10.64 \pm (-13.65/2)$	+ -	3.81 17.46
120 minutes (in/hr)	9.35	Compaction $f_{120\ min} = 9.35 \pm (C/2)$ $f_{120\ min} = 9.35 \pm (-12.69/2)$	+ -	3.01 15.70

Table 3-9. Clay texture soil results of the factorial analysis effects for each parameter.

Parameter	Average Value	Important Effects/ Model Equation	Moisture x Compaction	Model Value
f_o (in/hr)	7.25	Moisture x Compaction $f_o = 7.25 \pm (MC/2)$ $f_o = 7.25 \pm (5.85/2)$	+ -	10.18 4.33
f_c (in/hr)	2.26	Moisture x Compaction $f_c = 2.26 \pm (MC/2)$ $f_c = 2.26 \pm (3.49/2)$	+ -	4.00 0.51
k	5.96	Moisture x Compaction $k = 5.96 \pm (MC/2)$ $k = 5.96 \pm (0.43/2)$	+ -	6.17 5.74
15 minutes (in/hr)	4.22	Moisture x Compaction $f_{15\ min} = 4.22 \pm (MC/2)$ $f_{15\ min} = 4.22 + (3.84/2)$	+ -	6.14 2.30
30 minutes (in/hr)	3.45	Moisture x Compaction $f_{30\ min} = 3.45 \pm (MC/2)$ $f_{30\ min} = 3.45 + (3.41/2)$	+ -	5.15 1.74
60 minutes (in/hr)	2.97	Moisture x Compaction $f_{60\ min} = 2.97 \pm (MC/2)$ $f_{15\ min} = 2.97 + (3.29/2)$	+ -	4.62 1.33
120 minutes (in/hr)	2.60	Moisture x Compaction $f_{120\ min} = 2.60 \pm (MC/2)$ $f_{120\ min} = 2.60 \pm (3.25/2)$	+ -	4.22 0.97

Effects of Age on Infiltration Parameters

There may be some recovery of infiltration rates over time due to plant root activity, soil insects and small burrowing animals reducing soil compaction. Roger Bannerman at the Wisconsin DNR (personal communication) has supported soil scientists from the University of Wisconsin to examine potential recovery of infiltration capacity with time after development. The University of Wisconsin tests were conducted with loam soils and preliminary findings indicated that up to several decades were needed for natural recovery of infiltration capacity. UAB hydrology classes have examined the use of lawn aerators to speed up this recovery, but with poor success (most of the tests were conducted on extremely dry, clayey soils). Data collected during these current tests were evaluated to also examine effects of development age on infiltration.

Turf age was considered when choosing test locations. Unfortunately, the test locations that were selected had insufficient age variations in all groupings to include this variable in the complete factorial analysis. Scatter plots were therefore constructed to determine if the turf age had an obvious visual influence on infiltration rates. A plot was prepared for each infiltration parameter to test for changes over time. Extreme values for the Horton parameters f_o and f_c seemed to increase over time for all soil groups, except the noncompact sand (Figures 3-21 through 3-28). The infiltration capacity (f_c) for noncompact sand appeared to actually decrease over time (possibly due to siltation). The plots for the other parameters, which are not shown, had highly random results with no apparent relationships to age, even for the extreme values.

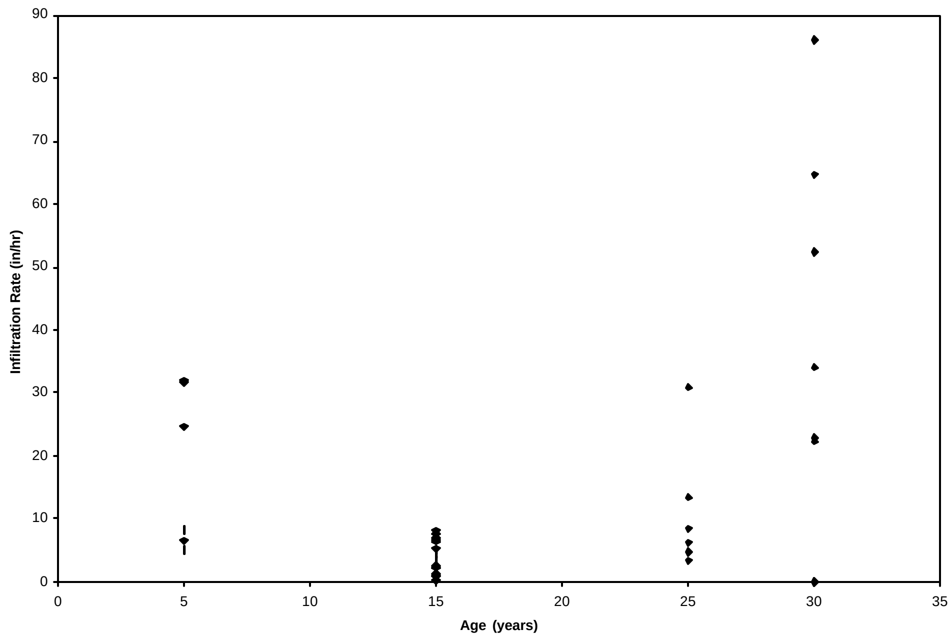


Figure 3-21. f_o vs. age for sand – compact.

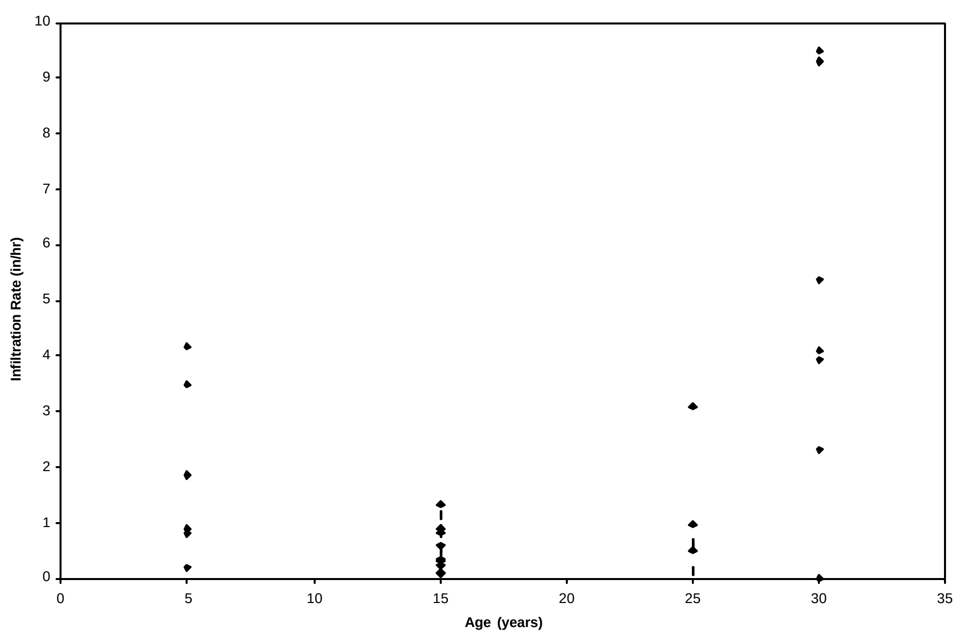


Figure 3-22. f_c vs. age for sand – compact.

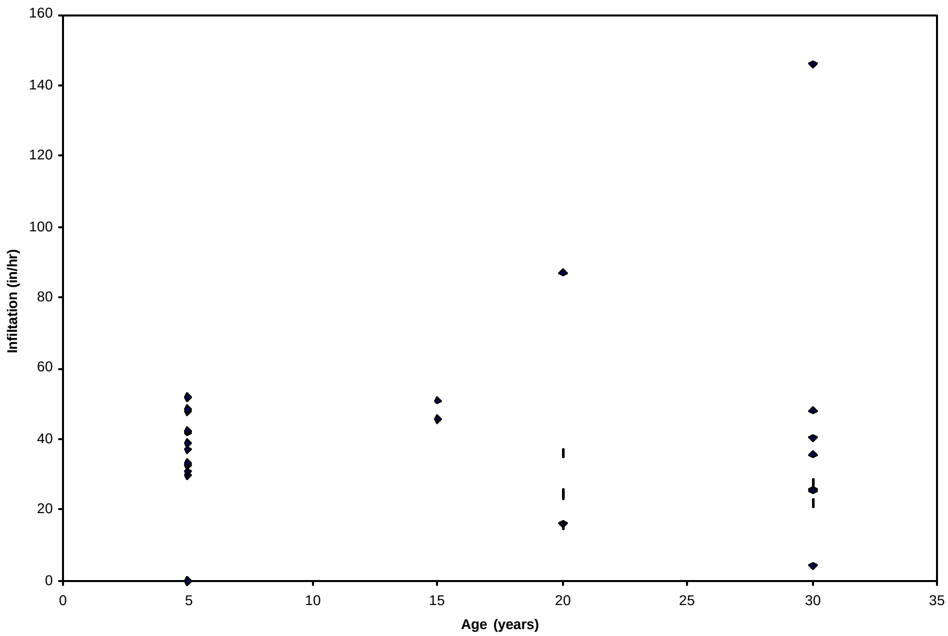


Figure 3-23. f_o vs. age for sand – noncompact.

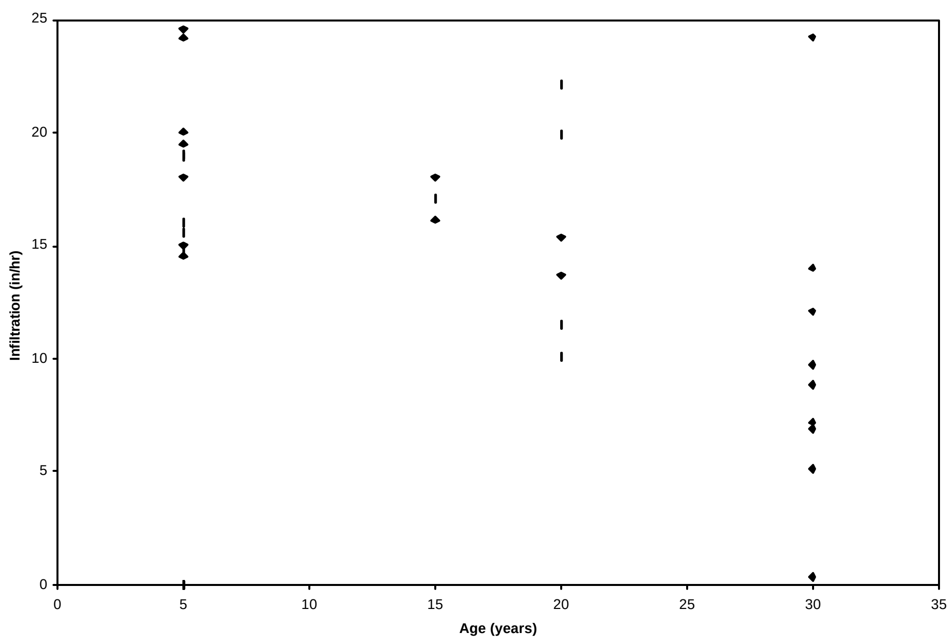


Figure 3-24. f_c vs. age for sand – noncompact.

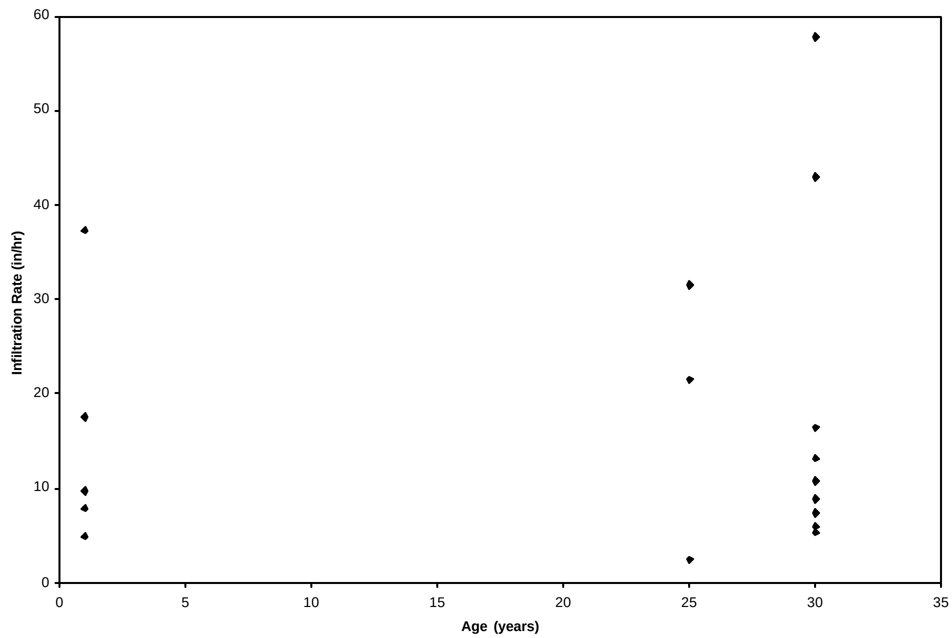


Figure 3-25. f_o vs. age for dry noncompact clay

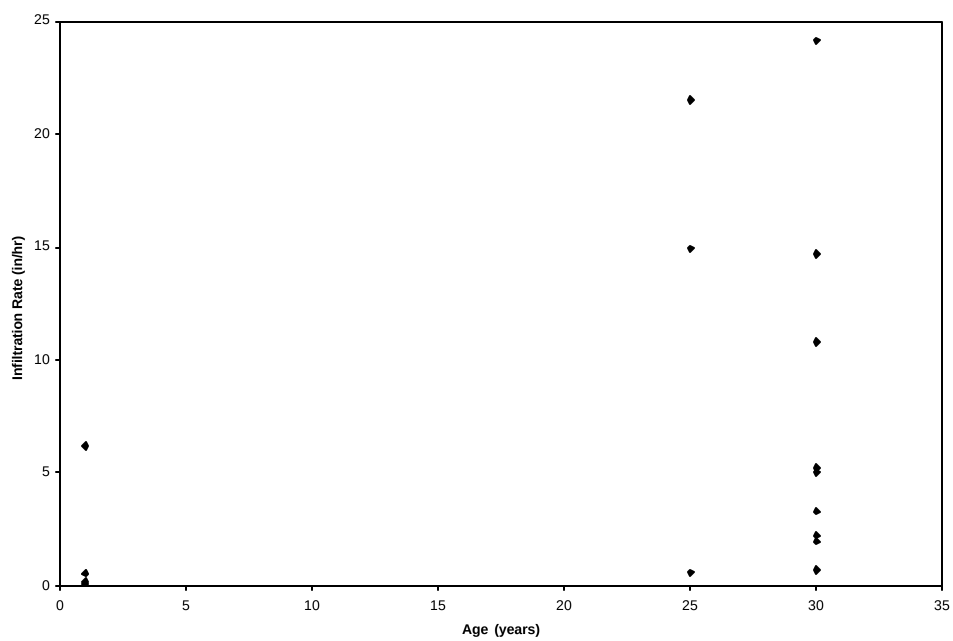


Figure 3-26. f_c vs. age for dry noncompact clay

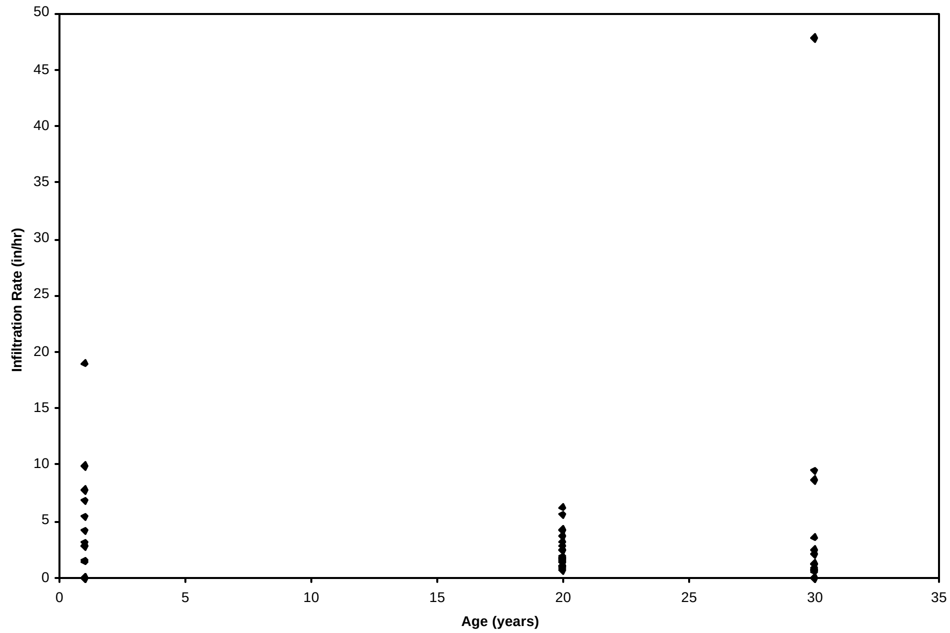


Figure 3-27. f_o vs. age for clay- dry compact, wet compact and wet noncompact.

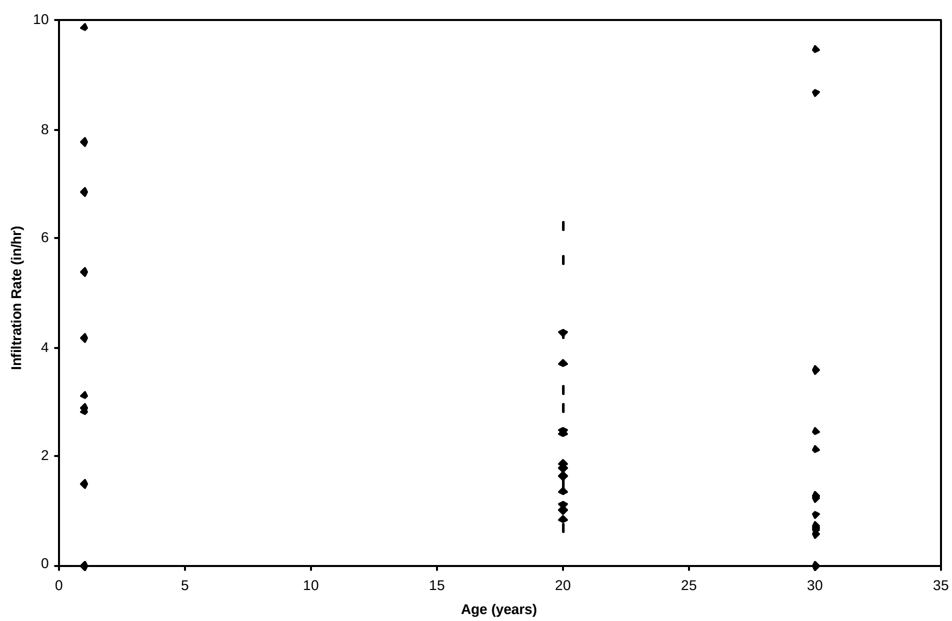


Figure 3-28. f_c vs. age for clay- dry compact, wet compact and wet noncompact.